The Ohio State University
Campus as a Living Laboratory

Green Roof Bike Shelters and the Ohio State Wetlands

By Rhys Davis, James Burpee, Emma Matcham,
Anthony Carlozzo, and Samuel Reed

ENR 2367
OSU School of Environment and Natural Resources

December 2014

A program of Energy Services and Sustainability
Aparna Dial, University Director, Energy Services and Sustainability
Dial.15@osu.edu

Table of Contents:

Introduction

The Wilma H. Schiermeier Wetlands at The Ohio State University are used for important research in a variety of scientific fields, such as ecology, biology, and environmental science. Many researchers, students, and professionals frequent the labs and resources located there. Transportation is always difficult when traveling to Ohio State buildings far from central campus, and the wetlands are no exception. An effective way to encourage sustainable travel while promoting utilization of the wetlands is to add more bike storage adjacent to the existing bike racks. In keeping with the core purpose of the wetlands, university, and community, we propose building a green roof enclosure over the new bike rack. This green roof would have many economic and non-economic benefits, and would also be a first step towards similar bike storage systems around campus.

Purpose

Adding bike racks to the wetlands would help solve current transportation problems. However, adding more bike racks alone will not necessarily be enough to encourage students, researchers, and visitors to ride their bikes, due to the unspectacular nature of bike racks. If the bike racks were added in tandem to a project that displayed the importance and purpose of the wetlands, while helping improve the health of the environment, both the new bike racks and the wetlands as a whole would get increased attention. Adding a green roof structure to cover both the new and existing bike racks at the wetlands would create an aesthetically pleasing and environmentally friendly place to park bikes, while still encouraging more bike traffic to the wetlands.

As shown in Figure 1, the proposed bike racks would be added in a 4 x 4 feet area that is currently a patch of grass in between the existing bike racks and the sidewalk to the north. There is room for four new inverse-U bike racks, which would increase bike storage capacity by eight, from 16 to 24. This would then be enough room for virtually all events held at the wetlands. The green roof, with dimensions of about 18 x 4 x 8 feet, would stretch from the start of the existing bike racks to the edge of the sidewalk to the north. This would allow people to walk under the green roof every time they enter the wetlands facility.

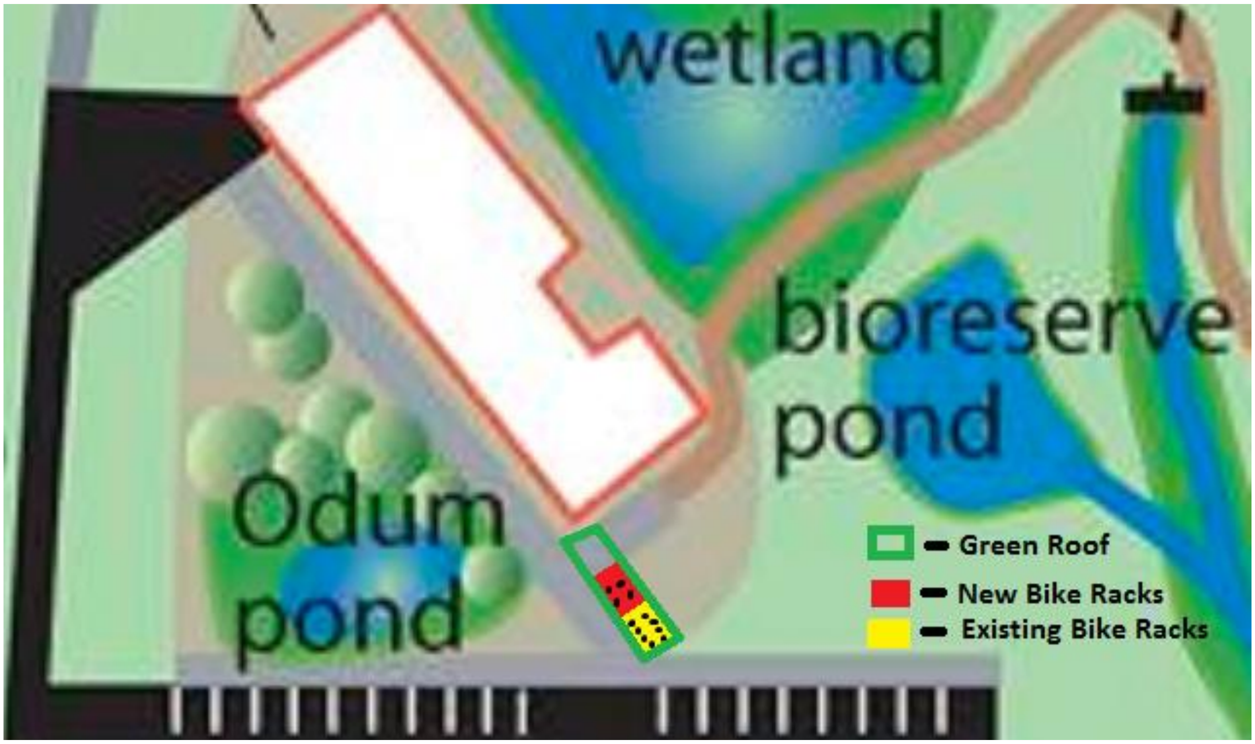

Figure 1: Proposed project building area (Batson, Mander, & Mitsch, 2012). This figure shows where the green roof and new bike racks would be added in relation to the wetlands.

To implement this proposed project, the following steps must be taken. First, the bike racks must be purchased, the grass patch must be dug up, and concrete must be laid to place the bike racks in. For the green roof, the structure must be designed to withstand all possible weather and external forces, the soil and waterproofing layers must be determined, and the plant types and planting methods must be chosen.

Simple Bike Racks

Transportation is a factor that limits use of the wetlands. Parking is limited, and some students do not have cars. The nearest CABS bus stop is approximately 500 meters away, as shown in Figure 2. This stop is not labeled to make directions to the wetlands clear. Since car and bus transportation is limited, the wetlands should invest in bike infrastructure. Biking will be a reasonable solution for students since many already own bikes. The facility is roughly a mile from main campus and is even located along the Olentangy Trail, a bike path that runs along the Olentangy River. This solution will also benefit the environment, since driving a mile releases one pound of CO_2 (Gotschi & Mills, 2008) whereas bikes have zero emissions. Bike transportation to the wetlands should be encouraged, and there are many ways to do that.

Figure 2: CABS Stops in Relation to Wetlands (CABS Area Bus Service, n.d.). This map shows the distance from the nearest CABS bus stop to the wetlands.

As previously mentioned, there are eight inverse-U bike racks at the wetlands that can house a maximum of 16 bikes. Most classes, conferences, and tours that are held at the facility call for 20 or more people to travel to the wetlands at any one time. This means that some people would either have to drive, take the bus and get off at a stop far from the wetlands, or attach their bike to a tree or street sign in order to access the facility. None of those options are beneficial for the traveler or the wetlands, and adding more bike racks encourages people to make the short, easy bike ride from campus using either the Olentangy Trail or Olentangy River Road. The proposed new racks would allow eight additional bikes to be parked. This would allow an entire class to find adequate parking. These new racks would also be inverse-U racks since they are very space efficient and secure (NYC Department of City Planning, n.d.). See Figure 3 for an example of these bike racks.

Figure 3: Inverse-U Bike Rack (NYC Department of City Planning, n.d.). This is the type of bike rack that would be implemented in proposed wetlands bike rack project.

In addition to adding infrastructure to the wetlands, there are social and educational ways to encourage biking. One recommendation is to encourage people to find cycling buddies to ride with. This increases biker safety and comfort. Educating people on environmental and economic benefits of cycling is also effective for increasing bike commuting (de Geus, de Bourdeaudhuij, & Meeusen, 2008). Increasing educational signage about safe cycling and different routes may also encourage more students to bike. Classmates can arrange to bike together, or professors can encourage safe cycling practices like wearing helmets and signaling to turn. These are all solutions that work well for classes since many students will be coming from main campus at the same time.

One of the consequences of adding bike racks would be environmental disruption due to construction. Pollutants that settle on a non-porous surface, such as cement, can run into the wetlands during a rain event. Because this area is used for water quality research, we want to minimize water pollution; therefore, a green roof bike shelter appears to be a good solution to this and many other problems.

Green Roof

Green Roofs in the Columbus Area

This project would not be the first green roof implemented on the Columbus campus of Ohio State. A green roof was installed on the roof of Howlett Hall in 2013 to be part of the university's Chadwick Arboretum and Learning Gardens. A bicycle rack with a green roof would not be the first in the Columbus area either. In 2012, the city of Columbus was awarded an Energy Efficiency and Conservation Block Grant. This was then used to install six new bicycle racks in the downtown area, each covered by a green roof. Jungles et al. (2013) found that a familiarity with green roofs and basic knowledge about their functions were factors that positively influenced people's attitudes towards them.

The implementation of this green roof bike shelter could positively influence people's attitudes and reactions towards green roofs in general, seeing as "increased exposure can only be positive for the green roof industry" (Jungels, Rakow, Allred, & Skelly, 2013). This new green roof bicycle rack would increase visitor's exposure to green roofs, which is then beneficial to other green roof projects in the area. As people's reactions to the green roofs become more positive, the OSU Wetland's green roof bicycle rack can become a springboard for other projects of the same nature around Ohio State's main campus and the Columbus area as a whole. This then creates a cycle of positive reinforcement, where people who have knowledge of the green roofs that already exist will support the implementation of new green roofs.

Science Behind the Roof and Potential Benefits

Green roofs provide an easy, natural, and cost-effective way to reduce man-made carbon emissions and harmful water runoff. They also help cool the surrounding area and absorb energy from the sun. Wetland-specific benefits include absorbing some of the local air pollutants and also increasing the biodiversity of flora that exists by adding different, non-invasive plant species to the roof. While the motivation behind most green roof installations is to lower energy costs in the buildings that they cover, they have many other economic benefits to go along with the environmental benefits. Using green roofs for external structures like sheds and bike rack shelters is not unprecedented, and the process of building these small green roof structures is becoming standardized.

The green roof industry, previously reserved for big companies and organizations trying to cut energy costs while being visibly sustainable, has moved towards smaller, personal structures because of the increase in standardization for the components and building process. In his book *Small Green Roofs: Low-Tech Options for Greener Living,* Nigel Dunnett studies over forty small green roof structures and analyzes their costs, specifications, and successes or failures. Specifically, one of the structures studied was a wooden bicycle shelter at the Langdon Conservation Centre in Essex, England. It was designed in 2000 to encourage people to bike to the area while educating people on the importance of green roofs and practicing sustainable construction. According to Dunnett, "The bicycle shelter and roof have been successful in giving visitors an intimate small-scale example of sustainable construction and living roofs within a wildlife trust reserve" (Dunnett, 2011). This success parallels the goals involved with the green roof bicycle rack structure for the wetlands. It is clear that successful small-scale green roofs are possible and that they have positive impacts on the environment and ecosystem.

To start, building a green roof is one of the most effective ways to clean the local air, because plants can remove air pollutants and absorb carbon dioxide. In a study conducted by NASA, it was determined that the amount of harmful chemicals, such as formaldehyde and benzene, removed from the air by a household plant can be substantial. In a 24-hour period, different varieties of household plants removed at least 45% of formaldehyde initially present, 20% of benzene initially present, and 10% of trichloroethylene present (Wolverton, Douglas, & Bounds, 1989). The plants used in the study may be different than those used in the green roof, and the air pollutant reduction might be harder to measure in an open environment, but the trends should be similar.

The amount of carbon dioxide removed from the atmosphere by the green roof can also be quantified. According to a study by a group in Hong Kong, "In a sunny day, a green roof may lower the CO2 concentration in the nearby region as much as 2%" (Li et al., 2010). The amount of CO2 removed depends on wind and sunlight, but this is still a significant result.

Another environmental benefit of green roofs is the prevention of water runoff. In a study performed by a group from Italy, it was discovered that green roofs can significantly decrease water runoff, as seen in Figure 4. "Both shrub-vegetated and herbaceous modules intercepted and stored more than 90% of the rainfall during intense precipitation events, with no significant difference between the two vegetation types, and despite the different depth of the substrate in the two modules" (Nardini, Andri, & Crasso, 2011, p. 703-704). Not only is the level of water runoff mitigation impressive, but the fact that both types of green roofs had similar effects suggests that almost all kinds of green roofs should significantly reduce water runoff.

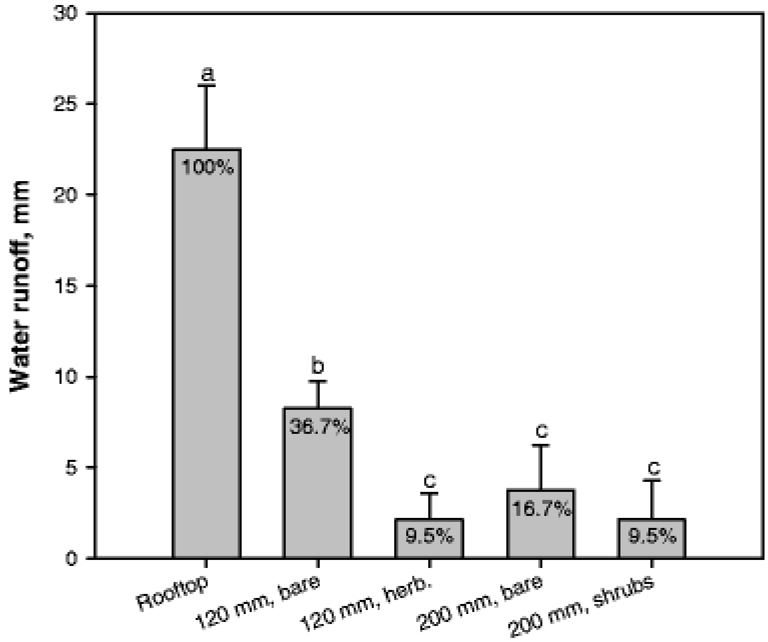

Figure 4: Water Runoff (Nardini et al., 2011). This graph shows how much water runoff was reduced by various plants and soil combinations.

Green roofs are also known to insulate the area underneath the structure while reducing the heat island effect in the surrounding area. In the previous Italian study, the temperature above and below a normal rooftop was compared to the temperature above and below different kinds of green roofs, as shown in Figure 5. On a typical summer day, the temperatures both above and below the green roofs were at least 15 degrees Celsius cooler than the bare rooftop, and the magnitude of daily temperature changes were also significantly less for the green roofs (Nardini et al., 2011). This means that not only would the green roof cool the surrounding environment, but it would allow for the bicycles underneath it to remain cooler on hot summer days, while staying somewhat drier during the winter.

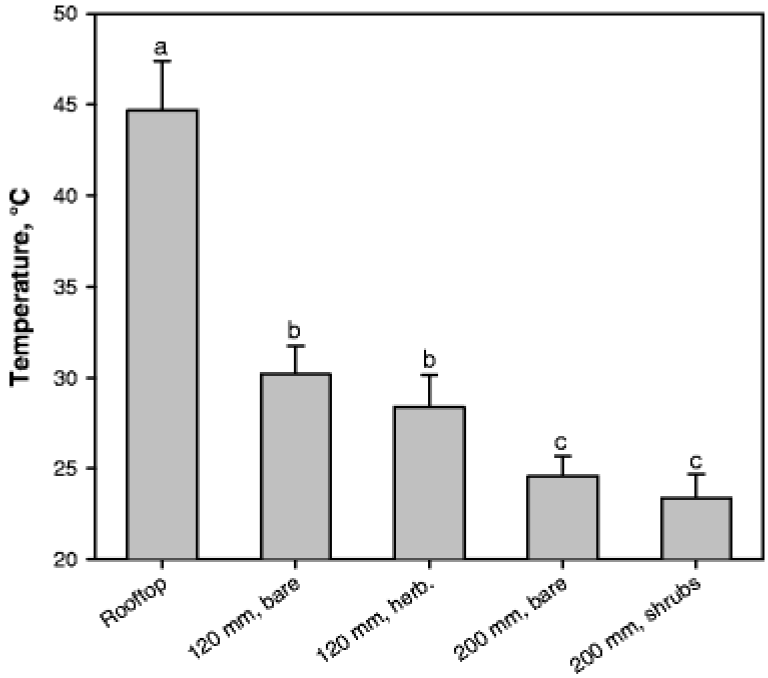

Figure 5: Green Roof Temperature Reduction (Nardini et al., 2011). This graph shows how much the roof temperatures were reduced by different plant and soil combinations.

All of the aforementioned environmental benefits can be impactful at the wetlands, because the research that goes on there involves a very delicate ecosystem. Any air pollutants or water runoff coming from the surrounding infrastructure that gets into the wetlands or any change in climate caused by the heat island effect could skew research results and negatively impact the wetland ecosystems. This makes the wetlands a suitable choice to build Ohio State's first green roof bike rack enclosure.

Not all of the benefits of the green roof are environmental. Green roofs provide some economic value, and while a lot of the savings involved with green roofs come from indoor energy savings, there is still value that the green roof bike rack can provide. Assuming that the roof is around 70 square feet, the university could save between 3 and 12 dollars in individual health care costs related to air pollution, according to a study from the University of Michigan (Clark, Adriaens, & Talbot, 2008). While this may not seem like much, some of the economic benefits are hard to quantify, like energy savings in the nearby wetlands building and overall aesthetic benefits that could increase productivity and bring in visitors to the university.

Ultimately, the most important aspect of this project would be setting a precedent around the university for building green roofs on structures that might not normally require them, so the economic benefits might be somewhat limited. Nevertheless, if enough structures similar to this project are built, it could have benefits for Ohio State's campus environment, while any savings would be an added bonus.

Green Roof Parameters

There are two main types of green roofs: intensive and extensive. Both are widely used, and both affect the types of plants that can be grown. In general, intensive green roofs are larger and more complex. They are commonly between four to eight inches deep and are much heavier than extensive roofs. Each square foot adds between 80 to 150 pounds of weight (Kaluvakolanu, 2006). This means that larger plants can be grown on one of these roofs. Shrubs and even trees can be seen on intensive green roofs. Larger plants and thicker soil levels results in larger and more complex drainage systems. These types of roofs require more frequent maintenance. Intensive green roofs are typically better equipped to handle foot traffic and have the appearance and feel of a garden.

The second type of green roof, the extensive green roof, is usually smaller and less massive than intensive roofs. These types of roofs are not designed for people to walk on and can only support limited varieties of plants. Most roofs of this type have different grasses growing, with the occasional shrub. The extensive green roof only adds 12-50 pounds per square foot, which is marginal compared to intensive roofs. Only one or two inches of soil are required for the plants used to grow (Kaluvakolanu, 2006). Because of these factors, much less maintenance is necessary for these roofs, and a simple drainage system is used instead of the more complex one mentioned above.

Bike racks in downtown Columbus were designed and installed by MSI Design, and the green roofs over top the bike racks were put in by Buck and Sons. This type of green roof is an example of an extensive roof. It is not designed for any sort of foot traffic, but it is still effective in absorbing rainwater and making the downtown area "greener." The process of installation was not too labor-intensive, as all six green roofs were installed the same day. Each of the racks is approximately 10 x 27 feet, or 270 square feet, which is much bigger than the one proposed in this project. The first layer of the roof is a 40 mm liner, which has holes in it so that water drains easily. On top of the liner there is a module layer that is installed in pieces. Each of the pieces measures 1 x 2 feet, and has a thickness of approximately 4 inches. A pea gravel and soil mixture is used for these pieces in which a classic sedum mix was planted. Of the 12 varieties of sedum mix available, the classic mix grew the best. Buck and Sons charged approximately 25 dollars per square foot, which is much cheaper than other green roofs. Because the roof doesn't sit high above the ground, ladders are not necessary during installation. The total coverage of the six green roofs for this project was slightly more than 1,000 square feet, as one of the roofs was much smaller than the rest.

The green roof bike shelter proposed in this project will try to model these downtown designs while using less expensive methods and materials. The proposed green roof bike shelter would also be smaller than those found in downtown Columbus. Megan Meier of Higher Ground Green Roofs, LLC, suggested that the green roof structure should have a four-inch lip with leaking holes for drainage, much like the downtown structures. Also, she suggested that for the drainage layer of the roof, a material called J-Drain be used. J-Drain is a relatively cheap man-made material that is lightweight but strong enough to prevent root penetration. She also mentioned that a waterproofing membrane was not necessary because the structure was not running on top of a building, so leaks are not as much of an issue. For the plant types, she suggested using a pre-grown vegetated mat of sedum (M. Meier, personal communication, October 28, 2014).

Aesthetics

A bicycle rack with a green roof would fit in very well with the aesthetics of the wetlands, even considering that research is the top priority at the facility. The aesthetics of the green roof are important because the roof is not one that covers the entire building, and thus it does not provide direct energy saving and insulation benefits. However, the green roof on the bicycle rack is much more visible than a green roof that would be covering the wetlands building, mostly due to the lower height of the proposed bicycle rack roof. Therefore, it also must have a higher emphasis on being aesthetically pleasing and fitting into the landscape of the wetlands.

Jungels et al. (2013) found that people have positive attitudes toward the aesthetics of green roofs and about green roofs in general. There are groups of people who have positive and negative attitudes towards green roofs, but these groups can be separated demographically. Those with college degrees and a college education are more likely to have positive attitudes towards green roofs and therefore support their implementation (Jungels et al., 2013). Due to the large number of college students, researchers, and professors that visit the area, the wetlands are an ideal site for constructing a green roof. While it has been determined that the Heffner Teaching and Research Building does not have the proper infrastructure to implement a green roof on the building itself, a green roof over a bicycle rack may be a better alternative.

When people have negative attitudes towards green roofs, they are generally attributed to people thinking the green roofs looked messy and "out of place" (Jungels et al., 2013). A study by Zheng, Zhang, and Chen (2013) found that some college students prefer clean landscapes to messy ones, but for students majoring in environmental sciences the opposite was true. Students who were majoring in environmental sciences actually preferred a landscape that was "messier" and included more wildlife. This is important because the vast majority of people who visit the wetlands are students and faculty in the School of Environment and Natural Resources. These students would most likely support the implementation of a green roof bicycle rack to improve the aesthetics of the wetlands landscape.

The type of vegetation used for a green roof is very important for both functionality and overall aesthetic appeal. Sedum and perennial roofs have been the most positively received types of vegetation, while grass dominated green roofs are less well received (Jungels et al., 2013). This is important in determining the vegetation to incorporate into the OSU Wetland's green roof bicycle rack so that it can be as aesthetically pleasing as possible. While perennial dominated roofs have been found to receive the highest aesthetic ratings, they are also the vegetation that requires the most maintenance and has the highest initial cost of construction (Jungels et al., 2013). The most cost-effective alternative to semi-intensive vegetation, such as perennials, is a sedum roof. In the study by Jungels et al. (2013) sedum roofs received positive reactions when surveyed for their aesthetic appeal. The OSU Wetland's bicycle rack green roof should therefore use a sedum mixture due to its low cost and aesthetic appeal. By installing a clean-cut green roof, the aesthetics should be attractive to everyone that walks or rides past it.

The surrounding landscape also has an impact on how a green roof is received. A green roof should add to the surrounding landscape by either adding complexity to an otherwise simple space, or by complementing the landscape with similar styles (Jungels et al., 2013). A green roof bicycle rack would then fit in with the landscape of the wetlands because it meshes with the preexisting environmental landscape of the surrounding area. This would then add a new dimension to attract visitors to the wetlands.

Discussion of Potential Drawbacks of the Green Roof Bike Shelter

To some, the green roof is seen as an unneeded expense that increases costs and leads to more problems than it solves. Each of these assumptions can be true, but must be accounted for holistically. In other words, when building a green roof, it is an absolute necessity to look at the big picture throughout the process. The benefits are likely to outweigh the expenses or perceived problems.

Cost certainly can be an issue, but this logistic must be taken into account from the long-term point of view. As previously mentioned, green roofs are highly aesthetically pleasing and are seen as interesting in the public eye; therefore, this could lead to further retention and visitation of wetland guests. People may be drawn to the area surrounding the wetlands, especially since this would be the first green roof bike shelter built on Ohio State's campus. In order to address short-term costs, the group has applied for the Coca-Cola Sustainability Grant so that some of the overall costs for the Wetlands can be alleviated.

The other problem brought up by critics is the question of upkeep within the vegetated roof. Since the plants on the roof are most likely going to be drought-resistant, concerns about water are circumvented; nevertheless, the question of how weeds can affect the roof is of concern. To some, weeds may lead to a degradation of the overall aesthetic quality of the roof. This problem can be negated if certain vegetation is used. In many instances, a drought-resistant, hydrophilic, and non-invasive plant cover called "sedum" can be utilized to deter increased weed growth. With the use of sedum, not only are weeds largely prevented, but the overall water retention is around the same as that found in native plants. There are multiple species of sedum available, from *Phedimus takesimensis* or the "Golden Carpet" to *Sedum hybridum* or "Immergrunchen" (M. Meier, personal correspondence, November 17, 2014). The wetlands would then be able to mix and match which color or type should be planted in order to optimize both success and beauty.

If one were to use native plants, one would just need to allow some form of extraneous vegetative growth. In fact, a diverse array of plants – including some crabgrass – could be just as aesthetically pleasing as sedum. Seeing as the nutrients and soil depth are extremely limited within a green roof, it is highly unlikely that the area will become overgrown. Plants can only grow where there are enough nutrients to lead to proliferation; nevertheless, it is highly unlikely that Ohio State would want weed growth in these green roofs. Sedum is the ecologically healthy and effective way to both appeal to maintenance workers and the general public's eye.

Conclusion

In sum, the green roof bike rack is not only a feasible and appealing project, but could also lead to various benefits for the wetlands. Increased bike storage provided by the structure will allow more students to visit or take classes at the wetlands. The wetlands are also an appropriate location for this structure because the green roof bike rack would mimic the wetland's ecological processes and benefits. This in turn puts more emphasis on the living environment present at the wetlands. If this project is successful and popular among those visiting and working at the wetlands, it could then be used as a template for other structures around campus.

Through a green roof bike rack, the wetlands could increase the overall beauty of the area, create an infrastructure that supports more visitors, and decrease their environmental footprint. From a holistic point of view, by accomplishing projects such as these, not only does the area become more aesthetically pleasing and sustainable, but it becomes truly one-of-a-kind.

References

Batson, J. A., Mander, Ulo, & Mitsch, W. J. (2012). Denitrification and a Nitrogen Budget of Created Riparian Wetlands. *Journal of Environmental Quality*, *41*(6), 2024. Retrieved October 29, 2014, from http://dx.doi.org/10.2134/jeq2011.0449

CABS Area Bus Service 2014-2015. (2014). [Map of OSU campus bus routes and schedule of frequencies]. Ohio State Transportation and Traffic Management. Retrieved from http://ttm.osu.edu/sites/default/files/attached-files/CABS_system_map_1415.pdf

Clark, C., Adriaens, P., & Talbot, F. B. (2008). Green roof valuation: A probabilistic economic analysis of environmental benefits. *Environmental Science & Technology*, 42 (6), 2155-2161.

ColumbUS. (2014). Green roof- Lazarus building. Retrieved from http://downtowncolumbus.com/home/moving-forward/lazarus-building/green-roof

Dunnett, N. (2011). *Small green roofs: Low-tech options for greener living*. Portland, OR: Timber Press.

de Geus, B., de Bourdeaudhuij, I., & Meeusen, R. (2008). Psychological and environmental factors associated with cycling for transport among a working population. *Oxford Journal Health Education Research*, 42(4), 697-708. Retrieved from http://her.oxfordjournals.org/content/23/4/697.full.pdf

Gotschi, T., Mills, K. (2008). Active transportation for America: The case for federal investment in bicycling and walking. Retrieved from http://www.railstotrails.org/resources/documents/whatwedo/atfa/atfa_20081020.pdf

Jungels, J., Rakow, D. A., Allred, S. B., & Skelly, S. M. (2013). Attitudes and aesthetic reactions toward green roofs in the Northeastern United States. *Landscape and Urban Planning, 117*, 13-21. doi: 10.1016/j.landurbplan.2013.04.013

Kaluvakolanu, P. (2006). History of Greenroofs. Retrieved from http://www.ltu.edu/water/greenroofs_history.asp

Li, J., Wai, O., Li, Y., Zhan, J., Ho, Y., Li, J., & Lam, E. (2010). Effect of green roof on ambient CO2 concentration. *Building and Environment, 45*(12), 2644-2651.

Nardini, A., Andri, S., & Crasso, M. (2012). Influence of substrate depth and vegetation type on temperature and water runoff mitigation by extensive green roofs: shrubs versus herbaceous plants. *Urban Ecosystems*, 15(3), 697-708.

NYC Department of City Planning, Transportation Division. (1999). Bicycle parking system assessment. Retrieved from http://www.nyc.gov/html/dcp/pdf/transportation/bike_and_ride_pt3.pdf

Wolverton, B. C., Douglas, W. L., & Bounds, K. (1989) A study of interior landscape plants for indoor air pollution abatement. NASA Internet Archive. Retrieved from https://archive.org/details/nasa_techdoc_1

Zheng, B., Zhang, Y., & Chen, J. (2011). Preference to home landscape: Wildness or neatness? *Landscape and Urban Planning*, *99*(1), 1-8. doi: 10.1016/j.landurbplan.2010.08.006